TECHNICALLY SPEAKING

BY HAROLD KINLEY

Inside line-of-sight propagation

Don't be confused: radio line-of-sight isn't always the same as optical line-of-site

When a line-of-sight path exists between two antennas, the propagation loss is equal to free-space attenuation. Free-space propagation occurs in the far-field region. Optical line of sight does not necessarily provide radio line-of-sight conditions. It depends on the clearance of the Fresnel zone. Obviously, these terms need to be defined mathematically and literally before continuing.

Free-space attenuation

Free-space propagation loss increases by 6 decibels (dB) per octave of distance from the transmitter antenna. Technically speaking, it is 6 dB per octave of distance from the point where far-field propagation begins. Free-space attenuation is found from the formula in Equation 1, where A is path attenuation in decibels, F is frequency in megahertz and D is distance in miles. It is important to note that this formula assumes that the antennas on each end are half-wave dipoles. After all, it takes an antenna to radiate a signal and one to capture it.

Figure 1 shows a free-space link between two antennas operating at a frequency of 800 MHz at a distance of 15 miles. The path attenuation between the half-wave dipole antennas is 114 dB. This is the actual attenuation between the antenna terminals.

Far-field region

The far-field region is the region in which plane-wave propagation takes place. The beginning of the far-field region can be determined from the formula in Equation 2, where F is the distance (in feet) from the antenna where the far field begins, D is the largest dimension of the antenna (in feet) and λ is the wavelength in feet. Also, F must be much greater than both D and λ. The beginning of the far-field region should be no less than 10 wavelengths from the antenna. In the case of Figure 1, the half-wave antenna would have a dimension of 0.62 feet and λ would be 1.23 feet.

Plugging these figures into Equation 2 would yield a distance of 0.625 feet. Thus, the far-field region begins 0.625 feet from the antenna. Since F is not much greater then D or λ, the distance to the beginning of the far field should be taken as 10 wavelengths or approximately 12 feet. Relative to the 15-mile

Equation 1:

$$A = 32.7 + 20 \log F + 20 \log D$$

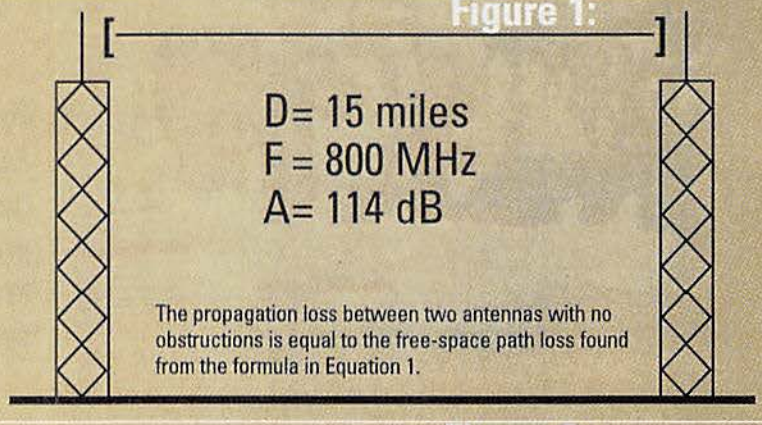
Equation 2:

$$F = \frac{2D^2}{\lambda}$$

Equation 3:

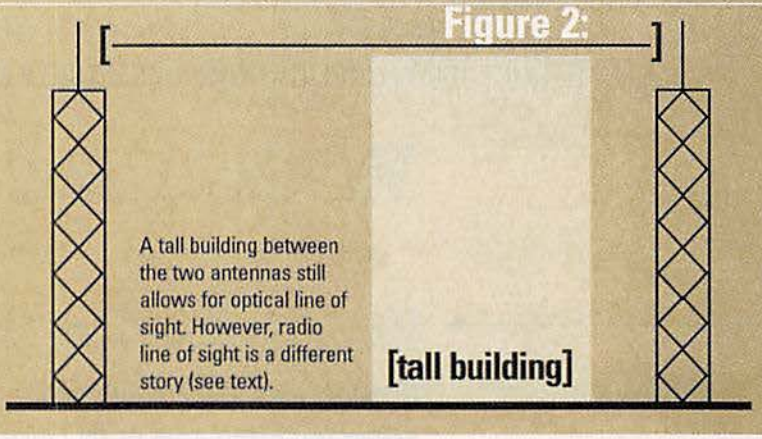
$$H = 2280 \sqrt{\frac{D_1 \times D_2}{F(D_1 + D_2)}}$$

Figure 1:



The propagation loss between two antennas with no obstructions is equal to the free-space path loss found from the formula in Equation 1.

Figure 2:



A tall building between the two antennas still allows for optical line of sight. However, radio line of sight is a different story (see text).

distance between the two antennas, 12 feet is insignificant.

Fresnel zones

Radio line of sight and optical line of sight are different. Even over a smooth earth with no obstructions, radio line of sight is limited by the earth's curvature. Radio wave propagation extends beyond optical line of sight. So, for radio line-of-sight calculations, the earth's radius is taken to be 1.333 times or 4/3 the normal radius. This produces a flatter earth between two fixed points.

In order to achieve true line-of-sight propagation (free space) the true line-of-sight path between two fixed antennas must clear any obstruction by more than the distance required for optical line of sight. Figure 2 shows a situation

While it isn't always necessary to achieve a line-of-site path between two fixed points, it does greatly improve the probability of communication to do so.

where optical line of sight exists between two antennas. However, Fresnel zones exist around the radio wave and at least 60 percent of the first Fresnel zone must clear any obstruction in order to achieve minimal degradation to the radio wave for virtual free-space propagation to exist. Figure 3 shows the first Fresnel zone around the radio wave and 60 percent of the first Fresnel zone is shown as the gray shaded area. Notice that the tall building penetrates the Fresnel zone such that not even 60 percent of the first Fresnel zone is clear. Thus, radio line of sight does not exist and the radio wave will be degraded by the obstruction.

Equation 3 can be used to calculate the Fresnel zone around the radio wave at any given point between the receiver and transmitter antennas. In Equation 3, H is the height (in feet) of the first Fresnel zone above optical line of sight. D_1 is equal to or less than D_2 and is measured in miles. F is the frequency in megahertz.

Figure 4 shows the first Fresnel zone is an ellipsoid surrounding the straight line between the two antennas. The sum of the distances between the two antennas and a common point on the ellipsoid is one-half wavelength greater than the straight line between the two antennas. For example, in Figure 4 the length of A-B-C is one-half wavelength greater than length A-C.

Suppose that the straight-line distance (A-C in Figure 4) between the two antennas is 25 miles, D_1 is 10 miles, and D_2 is 15 miles, while the operating frequency is 800 MHz. Plugging these

Figure 3:

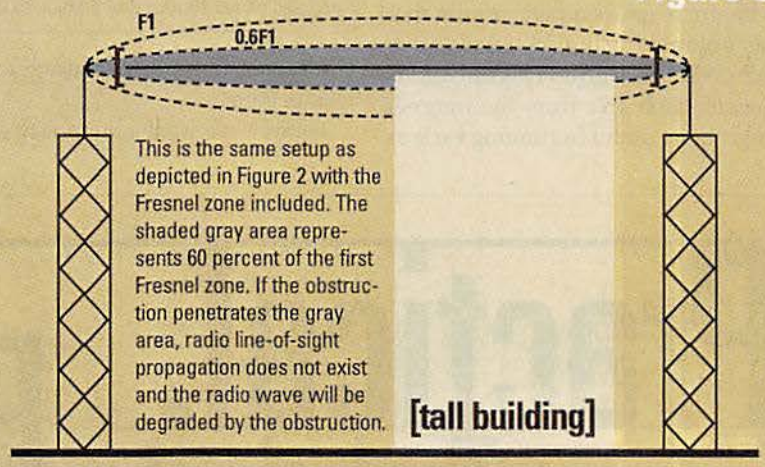
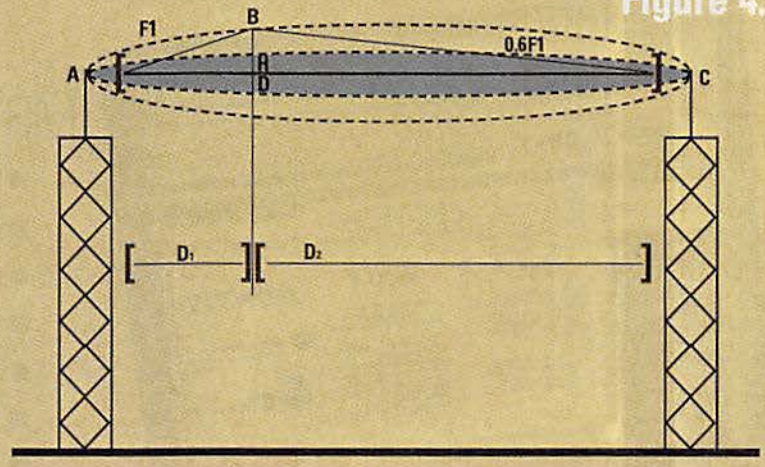

F1
0.6F1
This is the same setup as depicted in Figure 2 with the Fresnel zone included. The shaded gray area represents 60 percent of the first Fresnel zone. If the obstruction penetrates the gray area, radio line-of-sight propagation does not exist and the radio wave will be degraded by the obstruction.
[tall building]

Figure 4:



Path A-B-C is one-half wavelength longer than the path of A-C. The height of the first Fresnel zone, B-D, is determined from Equation 3 (see text for calculations).

numbers into Equation 3 yields a solution of 197.5 feet for the first Fresnel zone at distance D_1. The wavelength at 800 MHz is 1.2303 feet. The straight-line distance (A-C) is equal to 25 miles (132,000 feet or 107,290.9 wavelengths).

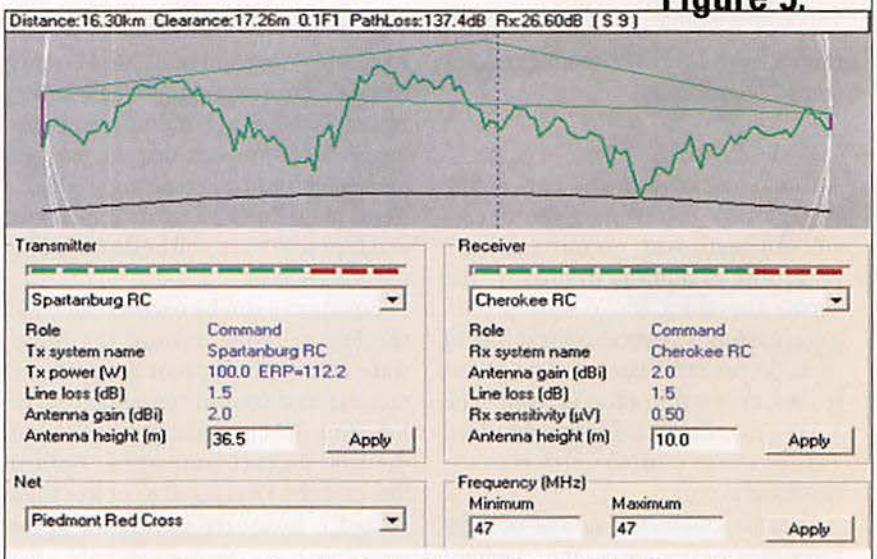
Using the Pythagorean theorem and substituting 197.5 feet for B-D, we find that the length of A-B is 52,800.37 feet or 42,916.66 wavelengths. Similarly, length B-C is calculated to be 79,200.25 feet or 64,374.74 wavelengths. The sum of A-B and B-C is 107,291.4 wavelengths, 0.5 wavelengths longer than A-C. This simply proves that the calculation for the height (B-D) of the first Fresnel zone is correct.

Path profile

Figure 5 shows a path profile that was obtained using software called Radio Mobile Deluxe.[1] This software is downloadable free from the Internet and is quite useful in running various communication scenarios using actual terrain data.

Figure 6 shows the boundary of 60 percent of the first Fresnel zone. Notice that 60 percent of the first Fresnel zone would not even clear smooth earth.

Figure 5:



This screen shot shows a path profile obtained from the Radio Mobile Deluxe software. Notice that the hilly terrain between the two antennas prevents line-of-sight-propagation and will cause serious degradation to the radio wave (see text for details).

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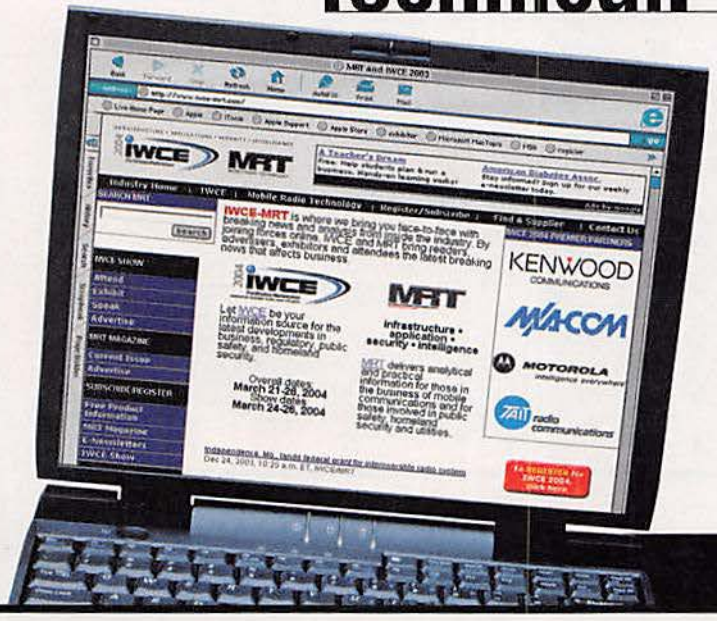

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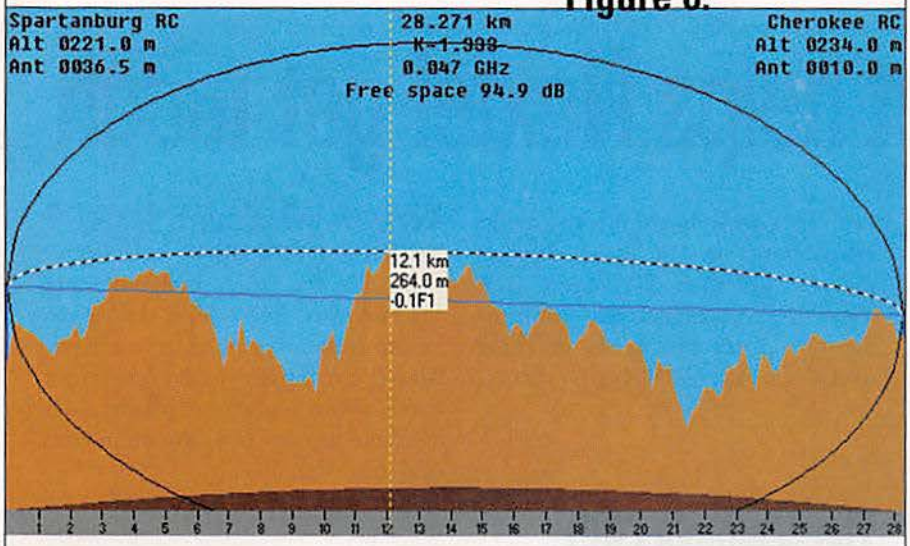
Figure 6:



This screen print shows the curvature of the earth at 1.333 times the normal radius. The terrain profile is clearly shown along with the boundary of 60 percent of the first Fresnel zone. This was obtained with the Radio Mobile Deluxe freeware.

Smooth earth is indicated by the black curvature at the bottom of the figure. With the hilly terrain between the two antennas, the signal would encounter severe attenuation.

Summary

As the frequency of operation increases, the boundary of the Fresnel zone draws in closer to the straight line. That is, at very high frequencies the propagation approaches optical line of sight. While it isn't always necessary to achieve a line-of-sight path between two fixed points, it does greatly improve the probability of communication to do so.

This is especially important in microwave links in order to achieve maximum reliability. Using a program such as Radio Mobile Deluxe with the proper terrain data (also free from the Internet) will allow one to determine necessary antenna heights on each end as well as other pertinent information for establishing a reliable communication link.

Until next time—stay tuned!

[1] Radio Mobile Deluxe was written by Roger Coude of Canada and made available as freeware.

Editor's note: The web site for Radio Mobile Deluxe is www.cplus.org/rmw/english1.html. ■

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